Rapid Manufacturing of Dental and Medical Parts via LaserCUSING® Technology using Titanium and CoCr Powder Materials

M. C. Sinirlioglu
General Manager, Hofmann Türk (HT Endüstri Teknolojileri), Turkey
(info@hofmannturk.com)

Abstract - **LaserCUSING® is based on the fusion of single-component metallic powder materials using a laser. This technology allows the layer-by-layer manufacturing of components from almost all metallic materials. Metallic powder is hereby fused layer for layer to produce a fully dense part. The typical layer thickness is between 20 and 50 µm.**

This paper describes the new era in the Rapid Manufacturing. The technology allows the customized production of dental crowns and bridges. Using special CoCr powder and the new fiber laser system, customized crowns and bridges can be produced automatically without any programming.

New machine concept meets special requirements for processing the reactive powder materials out of titanium alloys. In this paper the rapid manufacturing of customized and biocompatible titanium parts for medical purposes will also be described.

Keywords – **LaserCUSING®, Selective Laser Melting, Selective Laser Sintering, Rapid Manufacturing, Customized Rapid Manufacturing, Dental Bridges, Titan Implants**

I. INTRODUCTION

LaserCUSING® technology is based on the fusion of single-component metallic powder materials using a laser, and is similar to Selective Laser Melting (SLM). This method allows the layer-by-layer construction of components from almost all metallic materials. Metallic powder is hereby fully fused layer for layer to produce a 100% component density [Fig.1]. This dense structure allows high mechanical properties as much as (or more than) machined parts, and differs this technology from Selective Laser Sintering (SLS) [Fig.2].

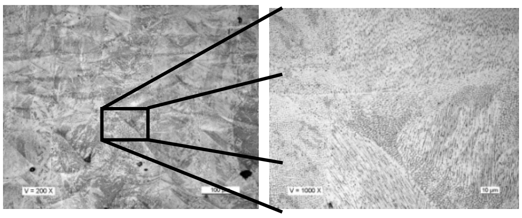

Fig. 1. The microstructure of a LaserCUSING® part [1]

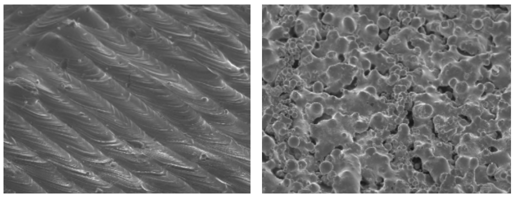

Fig. 2. Difference between LaserCUSING® (or SLM) and SLS
left: melted laser welds with optimized overlapping, produced with LaserCUSING® (or SLM) technology
right: structure of SLS [1]

Since the beginning of 21th century LaserCUSING® technology has been applied on hundreds of highly complicated 3D molds to provide mold inserts with very complicated cooling channels as shown in the Fig. 3. As a consequence of the optimally cooled mold inserts, cycle time reductions up to 60% are achieved. The compactness of the components ensures that no cooling water can escape. The deformations on the injection-molded part are minimized thanks to optimum mold cooling. [1-13]

Materials are produced in a powder form and have been developed specifically for this process. All powder materials are 100% compatible for re-use in subsequent construction processes. No fresh material has to be added after each production. Typical layer thickness for all materials is between 20 and 50 µm. Compositions of materials are corresponding to original materials like steels (316L, 1.2709), titanium (TiAl6V4 or pure Ti), aluminum, inconel (In 718) etc. Material properties are identical to those of the original material and allow these components to be employed under production conditions.

II. METHODOLOGY

This paper describes research and development activities of producing customized medical implants, dental crowns and bridges. Today leading dental companies starting to produce dental parts via rapid manufacturing technologies after years of research and development. The main reason for this purpose was the improvement of dental part quality. Normally dental crowns or bridges were produced with investment casting method, which makes a very porous structure. This manufacturing method leads to break of dental bridges on their joints. LaserCUSING® technology allows a fully dense microstructure. Another very important advantage of laser production is the availability of automated and customized serial production, which doesn't need any cavities like on investment casting.

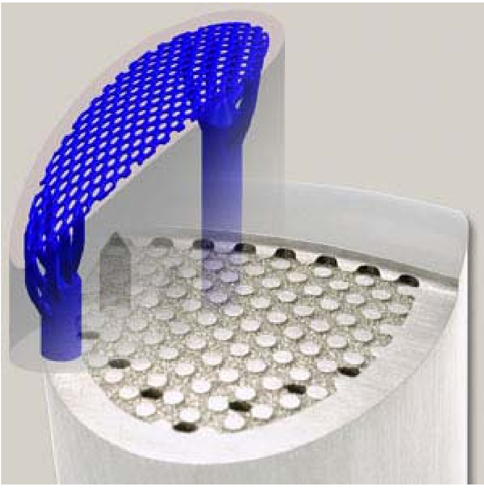

Fig. 3. A mould insert with conformal cooling channels [1]

Development tests were made on the M1cusing machine of Hofmann Türk Company by following machine properties:

Build envelope:	150 x 150 x 280 mm (x, y, z)
Layer thickness:	20-40 µm
Laser System:	200 W fiber laser (cw)
Inert gas:	nitrogen
Inert gas consumption:	approx. 1 m^3/h

For the density optimization different laser parameters and special scan strategies were investigated. Laser power, scan speed, weld overlapping, laser beam diameter and layer thickness are the most important parameters to get a 100% density on the best production speed.

Two different Cobalt-Chrome alloys investigated in this tests:

1. CL 110CoCr is a CoCr-alloy for medical applications, in particular suited for surgical implants, corresponding to ASTM F75.
2. A CoCr-alloy for dental components like crowns and bridges, which was developed in cooperation with a company from the dental sector. This product will be launched in autumn 2009.

III. RESULTS

A. Optimization of process parameters

Fig. 4 shows dental bridges with 215 units directly after a test process. LaserCUSING® technology allows the production of more than 400 units per day and more than 100.000 units per year. Fig. 5 shows a microanalysis of a dental bridge with almost 100% density produced by LaserCUSING® technology in optimization tests. On the other side Fig. 6 is an example for a micrograph of a dental part, which is produced by investment casting.

Fig. 4. Dental bridges produced by Hofmann Türk LaserCUSING® machine

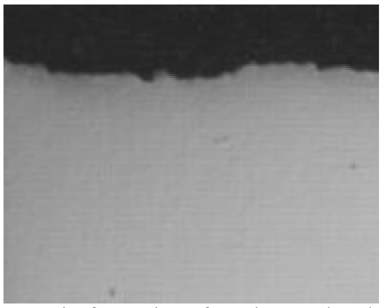

Fig. 5. Micrograph of a specimen from the new dental CoCr alloy produced by LaserCUSING® technology

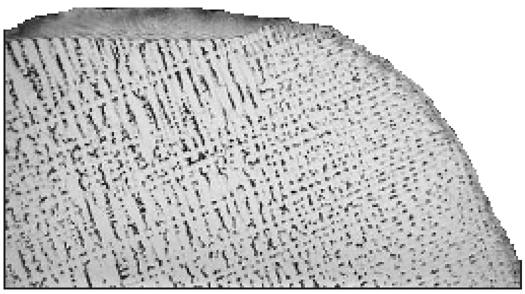

Fig. 6. Micrograph of a cast dental part [14]

B. Optimization of Production

Support structures on CAD data of dental bridge must be created before the LaserCUSING® process. These supports have to be strong enough to avoid the bending of bridges before stress relieving heat treatment.

On the other side they must be weak enough to provide an easy removal of supports. An automated supporting system of bridges was developed for the serial production of dental parts.

Fig. 7 shows a flow chart which is developed by Hofmann Türk for the production of CoCr dental crowns and bridges.

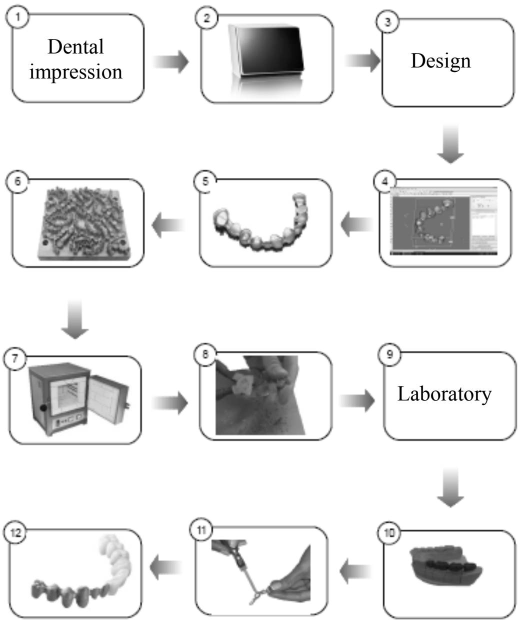

Fig. 7. Flow chart of the dental bridge or crown production developed by Hofmann Türk using LaserCUSING® technology

1. Creation of the dental impression
2. 3D scanning of the CAD image of the dental impression
3. Design of dental crown or bridge using 3D scanned images
4. Exporting and controlling stl data
5. Creating support structures on dental parts
6. Production of crowns and bridges via LaserCUSING® technology
7. Heat treatment process to reduce residual stresses
8. Removing the support structure and shot peening dental parts with alumina sand
9. Delivery of dental parts to the laboratory
10. Checking parts to fit on impressions
11. Post processing of dental bridges
12. Ceramic coating

C. Production of Titanium parts

Unlike steel powder, fine-grain powders of titanium alloys react with oxygen. Therefore the Hofmann Türk LaserCUSING® machine was optimized for the processing of titanium powder. The oxygen concentration and inert gas atmosphere is constantly monitored and controlled in the entire machine.

Powder materials of titanium alloys are characterized by their high oxygen affinity and have to be stored and processed without atmospheric oxygen in an inert gas atmosphere. Oxygen would otherwise react with the powder and lead to low mechanical parameters for the finished products or even component failures. This makes the production, storage and handling of titanium in a gas atmosphere indispensable. [1]

LaserCUSING® technology allow the rapid manufacturing of customized implants from titanium (TiAl6V4, pure titanium etc.). Fig. 8 shows a titanium implant produced with LaserCUSING® technology. Titanium parts are also optimized to have an almost 100% density (see Fig. 9)

IV. CONCLUSION

Rapid Manufacturing technology opens a new era enabling the customized production of dental crowns and bridges. Using special CoCr powder and the new fiber laser system customized crowns and bridges can be produced automatically without any programming. The LaserCUSING® (or SLM) technology allows an easier, cheaper and rapid production of dental parts with 100% density and high mechanical properties.


Fig. 8. A titanium part produced by LaserCUSING® technology [15]

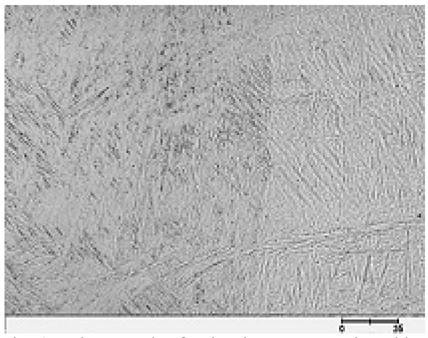
Fig. 9. Micrograph of a titanium part produced by LaserCUSING® technology [1]

The production of customized biocompatible medical implants from titanium and CoCr via rapid manufacturing is also gaining importance. The surface quality and mechanical properties must be improved and standardized for a serial production in the future.

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